

Practical nutritional recovery strategies for elite soccer players when limited time separates repeated matches.

RANCHORDAS, Mayur <<http://orcid.org/0000-0001-7995-9115>>, DAWSON, Joel T and RUSSELL, Mark

Available from Sheffield Hallam University Research Archive (SHURA) at:
<http://shura.shu.ac.uk/16933/>

This document is the author deposited version. You are advised to consult the publisher's version if you wish to cite from it.

Published version

RANCHORDAS, Mayur, DAWSON, Joel T and RUSSELL, Mark (2017). Practical nutritional recovery strategies for elite soccer players when limited time separates repeated matches. *Journal of the International Society of Sports Nutrition*, 14 (1), p. 35.

Copyright and re-use policy

See <http://shura.shu.ac.uk/information.html>

REVIEW

Open Access



Practical nutritional recovery strategies for elite soccer players when limited time separates repeated matches

Mayur Krachna Ranchordas^{1*}, Joel T. Dawson² and Mark Russell³

Abstract

Specific guidelines that aim to facilitate the recovery of soccer players from the demands of training and a congested fixture schedule are lacking; especially in relation to evidence-based nutritional recommendations. The importance of repeated high level performance and injury avoidance while addressing the challenges of fixture scheduling, travel to away venues, and training commitments requires a strategic and practically feasible method of implementing specific nutritional strategies. Here we present evidence-based guidelines regarding nutritional recovery strategies within the context of soccer. An emphasis is placed on providing practically applicable guidelines for facilitation of recovery when multiple matches are played within a short period of time (i.e. 48 h). Following match-play, the restoration of liver and muscle glycogen stores (via consumption of $\sim 1.2 \text{ g} \cdot \text{kg}^{-1} \cdot \text{h}^{-1}$ of carbohydrate) and augmentation of protein synthesis (via $\sim 40 \text{ g}$ of protein) should be prioritised in the first 20 min of recovery. Daily intakes of $6\text{--}10 \text{ g} \cdot \text{kg}^{-1}$ body mass of carbohydrate are recommended when limited time separates repeated matches while daily protein intakes of $>1.5 \text{ g} \cdot \text{kg}^{-1}$ body mass should be targeted; possibly in the form of multiple smaller feedings (e.g., $6 \times 20\text{--}40 \text{ g}$). At least 150% of the body mass lost during exercise should be consumed within 1 h and electrolytes added such that fluid losses are ameliorated. Strategic use of protein, leucine, creatine, polyphenols and omega-3 supplements could also offer practical means of enhancing post-match recovery.

Keywords: Soccer, Nutrition, Recovery, Polyphenols, Omega-3, Creatine, Fixture, Congestion

Background

Over the course of a 45 week season, professional European soccer teams may play in excess of 60 competitive matches [1, 2] and thus at specific times of the year, multiple matches will be played within a single week [1]. Notwithstanding the additional match demands of the pre-season period, it is common for players to compete in 2–3 matches within an 8 day period (see Fig. 1 for a typical weekly schedule for an English Premier League team) on multiple occasions throughout the season. It should be noted that the notion of limited recovery between soccer matches is not unique to the English Premier League as fixture congestion is also common among U.S. University teams as well as youth

teams who play multiple games in a weekend. Up to 120 h are required to restore disturbances in metabolic and physical performance indices that result from soccer match-play [3]. Injury risk has been observed to increase when less than 96 h separates games [1, 2] and the reduced recovery time between matches played in FIFA World Cup competitions is perceived to be a primary cause of injury in professional soccer players [4]. Therefore, the ability to facilitate post-match recovery is desirable.

Accumulated fatigue can arise from a repetition of matches and training performed within a short period of time (e.g., daily training with matches separated by $\sim 48 \text{ h}$; 5). The demands of a congested fixture schedule means that recovery duration may sometimes be less than optimal when seeking to maintain physical performance and a low injury rate. Indeed, a reported 6.2-fold higher injury rate occurred in players who played

* Correspondence: m.ranchordas@shu.ac.uk

¹Sheffield Hallam University, Academy of Sport & Physical Activity, A220 Collegiate Hall, Collegiate Crescent Campus, Sheffield S102BP, UK
Full list of author information is available at the end of the article



Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
			1 Soccer Training am Gym pm	2 Match Day minus 1 Light Training	3 League Fixture	4 Recovery Session am
5 FA Cup Fixture	6 Recovery Session am	7 Off	8 Soccer Training am Gym pm	9 Match Day minus 1 Light Training	10 League Fixture	11 Recovery Session am
12 Soccer Training am Gym pm	13 Match Day minus 1 Light Training	14 Champions League Fixture	15 Recovery Session am	16 Match Day minus 1 Light Training	17 League Fixture	18 Recovery Session am
19 Off	20 Match Day minus 1 Light Training	21 EFL Cup Fixture	22 Recovery Session am	23 Match Day minus 1 Light Training	24 League Fixture	25 Recovery Session am
26 Off	27 Match Day minus 1 Light Training	28 Champions League Fixture	29 Recovery Session am	30 Match Day minus 1 Light Training	31 League Fixture	

Fig. 1 A Typical monthly schedule for a top professional soccer club in the Premier League

two matches a week compared to one and the majority of these injuries (i.e., 76%) were reported to be caused by overuse [5]. As muscle injuries constitute almost one third of the time lost in men's professional soccer [6], it appears that amassed fatigue during a congested fixture period may contribute to both underperformance and/or elevated injury risk [3]; particularly in the final 15 min of a match [7]. Notably, when three games are played within a week, repeated sprint performance is compromised (more so after the second game) and muscle soreness is increased, knee range of motion is impaired, and muscle damage, oxidative stress, and inflammatory markers are perturbed [8]. While it must be acknowledged that the extent of exposure to periods of match congestion in professional soccer players may be limited [9], when such periods do occur, performance is likely compromised and injury risk may be elevated [7].

A number of interventions have been proposed to facilitate post-exercise recovery, including, but not limited to: cold water immersion, active recovery, compression garments, massage and electrical stimulation [10]; many of which are routinely used by professional soccer teams. However, nutritional strategies are amongst the most popular and accessible methods of facilitating restoration of performance and physiological perturbations following soccer-specific exercise. Despite the popularity of soccer, surprisingly few guidelines exist that seek to address the practical application of nutrition for recovery from soccer when limited time (e.g., ~48 h) separates

matches. The importance of optimised recovery strategies is particularly prevalent when congested fixture periods exist and implementation of them may be complicated by logistical issues such as late fixture times and demanding travel schedules. Therefore, the purpose of this review was to evaluate current knowledge regarding nutritional recovery strategies within the context of soccer. Our emphasis is on providing contextually relevant recommendations for facilitation of post-exercise recovery when multiple matches are played within a short period of time. We present practical strategies relating to the composition, quantity and timing of nutritional intake for the elite soccer player wishing to improve their recovery via evidence-based dietary strategies. Practical issues concerning the implementation of such strategies within the elite environment are also considered.

Method

Articles were retrieved in accordance with an extensive search in several databases including MEDLINE (1966–2016); SPORTDiscus (1966–2016); PubMed (1966–2016) and Google Scholar (1980–2015). The following search terms were used in various combinations: “recovery,” “nutrition,” “diet,” “food,” “soccer,” “football,” “supplements,” “ergogenic aids,” “glycogen re-synthesis,” “refuelling,” “repair,” “adaptation.” Only studies that were conducted using human participants were selected and references cited in the retrieved articles were also considered for inclusion.

Characterising the demands of soccer match-play

Soccer is a physically demanding intermittent sport which consists of recurrent high-intensity running, intensive soccer-specific actions and requirements for a high endurance capacity [11]. The game demands an ability to intersperse repeated actions at maximal or near-maximal intensity with periods of low-to-moderate intensity (including active recovery or passive rest) [12]. Accordingly, both anaerobic and aerobic energy pathways are required during match-play [11] as players typically cover distances of 9–12 km, and perform ~1350 activities (including a change of movement every 4–6 s) while executing ~220 runs at high speed [11] over 90 min; responses which may be exacerbated by involvement in extra-time [13, 14] in tournament scenarios.

Mean energy expenditure for soccer match-play has been estimated to be ~1106 kcal [15], and between 3439 and 3822 kcal·day⁻¹ for players undertaking daily training [16, 17]. Using the doubly labelled water technique, English Premier League soccer players have exhibited a state of energy balance (i.e., matching energy intake and expenditure: 3186 ± 368 vs 3566 ± 585 kcal·day⁻¹, respectively; [18], yet previous data from youth soccer players and using estimated markers of energy balance do not support such findings [19, 20]. Indeed, in youth players it has been reported that a mean daily energy deficit of 310 ± 399 kcal·day⁻¹ is common and heavy training days and matches result in the largest energy deficits of 502 ± 533 kcal·day⁻¹ [19]. It has also been reported that carbohydrate intake on a match-day and in the time preceding match-play was less than optimal [18]. While highlighting a possible performance-enhancement strategy to a single match, the implications of such practices may be compounded when multiple matches are played with a short turn-around time as the recovery nutrition in professional players may be compromised [18].

Similarly, in players with energy intakes that fail to balance expenditure, the predisposition of injury, accentuation of fatigue and suppression of the immune system may occur [21, 22]. On a day to day basis, there are large changes in energy expenditure depending on the type, intensity and duration of training [23]. Moreover, variability exists in the activity and energy demands of players that are dependent on the individual and position played within a team; both of which can be dictated by extraneous factors such as tactical role, quality of opponent, style of playing, and environmental factors [11]. It is therefore important that players periodise energy and macronutrient intake, particularly carbohydrate, according to requirements.

The importance of carbohydrate for soccer has been acknowledged since the early 1970's when muscle biopsy techniques identified compromised muscle glycogen stores following soccer match-play; a finding which had

negative ramifications for performance [24]. Indeed, a better between-half maintenance of total distance covered and higher movement intensities were achieved by players starting the game with higher muscle glycogen concentrations [24]. More recent studies have demonstrated a fibre-specific reduction in muscle glycogen concentration [25] with knee extensor maximal voluntary activation and peak torque responses shown to also be reduced [26]. Accordingly, over the course of 90 min, the intensity and frequency of explosive actions tend to reduce, resulting in a transient decline in physical performance [3]. Likewise, a high degree of muscle damage occurs as a result of exhaustive intermittent activities and regular unexpected changes of direction [27]. Consequently, refuelling and recovery nutrition are crucial components to promote muscle recovery and glycogen resynthesis. Additionally, recovery modalities and the nutrient intake/timing approach need to be strategically integrated to fully maximise muscle recovery and soccer-specific adaptations.

Recovery nutrition strategies

A clearly planned nutritional strategy can likely assist practitioners to facilitate the replenishing of glycogen stores, acceleration of muscle-damage repair and enhanced rehydration; all of which seek to improve subsequent performance. Commencing the immediate recovery phase as close to the end of the match as is reasonably possible will likely confer beneficial effects before continuation for several hours after until sleep occurs.

Refuelling after a match – The immediate recovery phase

The main focus immediately after a match is to replenish both liver and muscle glycogen stores through ingestion of adequate carbohydrate. For optimum glycogen resynthesis it is a prudent strategy to consume carbohydrate immediately after a game as glycogen-synthesising enzymes are most active during this time [28]; thus there is a potential 'window of opportunity' that players should seek to take advantage of. Indeed, when compared to immediate carbohydrate ingestion, delaying carbohydrate feeding until 2 h after exercise can result in lower muscle glycogen concentrations by 45% when assessed 4 h post-exercise [28]. Thus players should be encouraged to consume a recovery drink and/or snacks as soon as possible after a match ends. This can be achieved practically by providing several opportunities to consume carbohydrate-electrolyte drinks on the pitch, in the media suites for post-match interviews and in the changing rooms.

The amount and frequency of carbohydrate ingested is an important factor to consider during the immediate recovery period (i.e., within 20 min of match-play). Generally, the ingestion of 1–1.5 g·kg⁻¹·h⁻¹ of carbohydrate has been shown to benefit maximal glycogen

resynthesis in the first 4 h post-exercise [29]. Therefore, based on the upper limit of this recommendation, an 80 kg player would be advised to consume ~96 g of carbohydrate per hour in the hours after a game finishes, with a particular emphasis on achieving such rates during times of fixture congestion. Furthermore, during this initial stage of recovery, a strategy of frequent ingestion of carbohydrate (i.e., every 30 min) has been shown to induce greater glycogen resynthesis rates compared to a less regular (i.e., every 2 h) protocol [30]. Similarly, adding 0.2–0.5 g·kg⁻¹·day⁻¹ of protein to carbohydrate has been shown to stimulate glycogen resynthesis to a greater extent than consuming carbohydrate alone [31] but only when carbohydrate intake is less than 1.2 g·kg⁻¹·day⁻¹. It has been suggested that high glycaemic index (GI) foods may be preferable over moderate and low GI foods when the goal is to restore glycogen as quickly as possible [32–34].

The consumption of adequate quantities of carbohydrate in this post-match phase is likely the most beneficial aspect of carbohydrate recommendations. Accordingly, support staff should seek to provide food and drinks that are both tempting and practical to eat (see Tables 1, 2 and 3 for practical examples). Food options should be promoting a desire to eat such that sufficient amounts in agreement with recommended values are realised as a loss of appetite may exist in some players in the time shortly after matches. Support staff should ascertain the types of foods players are likely to eat in this immediate recovery phase as players may have individual cultural preferences.

The type of carbohydrate recommended in the immediate phase of recovery is high GI foods (see Table 1 for examples). High GI sources are proven to accelerate muscle glycogen resynthesis rates in the first 6 h of recovery compared to low GI sources, most likely due to malabsorption of low GI carbohydrate-rich foods [35].

However, the effect of high GI carbohydrate meals on subsequent soccer-specific performance still remains unclear, with no difference observed between high and low GI diets on endurance and sprint performance 24 h after 90 min of intermittent exercise [36]. It is the player's preference that should drive the decision as to whether solid or liquid forms of carbohydrate are ingested as both appear equally effective for muscle glycogen restoration [37].

From a practical perspective, the consumption of high amounts of carbohydrate required from food sources can bring about gastrointestinal problems so it is important that players have access to a mixture of fluid and solid foods to prevent such issues [38]. There is evidence to suggest that multiple transportable carbohydrates in the form of glucose and fructose increases gastric emptying and fluid delivery compared to glucose only [39, 40] thus drinks provided at the end of the match should contain multiple transportable carbohydrates. Due to the fact that liquid carbohydrate solutions can contribute to rehydration in conjunction with exogenous carbohydrate supply, carbohydrate-containing fluids may be more preferable for immediate ingestion when compared to solid foods. A selection of high GI drinks and snacks should be readily available in the changing room after a game (refer to Table 1 for a selection of recommended carbohydrate foods).

The co-ingestion of protein with carbohydrate has proven beneficial in the context of glycogen resynthesis when sub-optimal carbohydrate amounts were consumed via an augmentation of postprandial insulin secretion [41]. A similar increase in glycogen synthetic rate has been observed when 0.4 g·kg⁻¹·h⁻¹ of protein was added to 0.8 g·kg⁻¹·h⁻¹ of carbohydrate relative to ingesting 1.2 g·kg⁻¹·h⁻¹ of carbohydrate alone [30]. The inclusion of protein to sufficient carbohydrate intakes is advisable to aid glycogen re-synthesis and enhance muscle tissue repair

Table 1 Refuelling for the Immediate Recovery Phase 0–4 h

Strategy	Food Choices
<ul style="list-style-type: none"> Start to consume carbohydrate as soon as possible after the cessation of exercise taking full advantage of a 'window of opportunity' where high rates of glycogen storage present in the muscle. Aim to ingest a recovery snack or meal that provides approximately 1 g·kg⁻¹ body mass (e.g. 80 g for 80 kg player) per hour during the first 4 h of recovery until normal eating patterns are resumed. This strategy should be implemented after a high intensity fuel-depleting session or game when muscle fuel stores need to be fully maximised in a short time period before the next demanding exercise bout. Provide food and drinks that are both tempting and practical to eat that are appetite promoting so that the player will consume sufficient amounts to meet their fuel targets. The food provided could vary according to the environment in which the game is played as well as the time of the day. Support staff should ascertain the types of foods players are likely to eat in this immediate recovery phase as players may have individual cultural preferences. Creatine ingestion with carbohydrate will help restore important phosphocreatine stores in this short period. 	<p>Recovery snacks containing 50 g of CHO:</p> <ul style="list-style-type: none"> - 250–350 ml of milk-shake or fruit smoothie - 2 slices toast/bread/bagel with jam, banana or honey topping - 2 cereal bars - Large (300 g) baked potato with filling - 2 sport gels - 700–800 ml of sports drink - Fruit salad with 200 g of yoghurt - Sandwich with meat filling - Sports bar (check the label for content) - Rice cakes - Tortilla wraps with filling - Medium bowl of baked sweet potato wedges - A medium bag of popcorn - Thin base pizza slices (i.e., tortilla) with mixed toppings - Panini's with mixed fillings

Table 2 Repair and Adaptation for the Immediate Recovery Phase 0–4 h

Strategy	Food Choices
<ul style="list-style-type: none"> • Ingest a protein-rich high quality source that provides 30–40 g of protein (containing 6–9 g of essential amino acids) as soon as possible after exercise. Leucine in particular is an important amino acid for its anabolic stimulating properties. • Plan a feeding pattern which includes this optimal protein serving of 20–25 g along with other nutritional goals every 3–5 h to fully maximise recovery in the immediate phase. • Have a protein-rich snack before bed, which preferably contains casein (e.g. 200 g of cottage cheese or 40 g in a liquid supplement) to optimise protein synthesis overnight. 	<p>Rapidly digested protein sources containing 10 g to have in the immediate recovery phase:</p> <ul style="list-style-type: none"> - 300 ml milk, milkshake, flavoured milk - 20–30 g high protein sports bar (quantities dependent on the brand) - 10–15 g whey-based protein powder (quantities dependent on the brand) - 200 g Greek-style yogurt - 250 ml of low-fat custard

[42] (see Table 1). As milk or flavoured milk naturally contains a mixture of carbohydrate and protein, it may positively influence recovery and is likely a good choice of recovery beverage for lactose-tolerant players [43, 44].

Refuelling after a match - daily recovery between games

During a congested week (see Fig. 1), it is important to implement a carbohydrate feeding strategy that not only replenishes endogenous fuel stores but also seeks to fully maximise muscle glycogen concentrations in preparation for the next game as the 48 h post-exercise recovery period may also coincide with the 48 h period leading into the subsequent match. Optimal performance can largely be attributed to carbohydrate availability [45]. Notably, players consuming a high carbohydrate diet ($10 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ for one week improved repeated high intensity intermittent performance compared to players on a mixed diet ($5 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ carbohydrate; [46]. However, recent soccer-specific literature has failed to report an increase in glycogen concentrations above pre-match levels 48 h after a game, despite the ingestion of a high carbohydrate diet of up to $10 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ [11, 47]. Similarly, a carbohydrate rich diet with whey protein ingestion failed to increase glycogen resynthesis when compared to a normal diet [25]. Therefore, supercompensation of muscle glycogen concentrations has yet to be reported 48 h after a game; a response which is typically seen in sports such as cycling [48]. This may be attributed to the high eccentric component involved in soccer-specific movements with resulting muscle damage impairing glycogen resynthesis during recovery [47]. Fast twitch-muscle fibres in particular, had lower glycogen content in comparison to slow twitch fibres 48 h after a high carbohydrate diet [25]. Practically this could have implications on recovery time scale for the more 'explosive' players in the team who have a higher composition of these fibres in the muscle but more research is warranted in this area.

While carbohydrate recovery strategies in the 48 h after a game are less clear than endurance sports, it is difficult to recommend exact guidelines for the amount for optimal recovery. Nevertheless, a general guideline of

$6\text{--}10 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ is a prudent aim for elite soccer players in the days of muscle glycogen recovery/loading. This could be achieved through 3–4 main meals and regular carbohydrate snacking interspersed throughout the day (Table 1). This nutritional approach, coupled with acutely modulating training intensity and duration, will likely increase the availability of carbohydrate in the body in a week that involves 3 games in a 7-day period.

Repair and adaptation after a match – The immediate recovery phase

Exercise increases both muscle protein breakdown and protein synthesis [49]. However, prolonged periods of negative protein balance may result if synthesis rates are not periodically elevated through dietary protein consumption; a scenario that the elite player should seek to avoid when fixtures are congested. The effects of a high amount of eccentric actions during match-play, as well as impacts from tackles and challenges with the opposition, results in impaired muscle function [50] that must be restored. To repair damaged muscle fibres and stimulate molecular adaptation, the post-match nutrition strategy should target the promotion of protein synthesis and attenuation of muscle breakdown. It has recently been shown that consuming 40 g of protein rather than just 20 g after exercise stimulates greater myofibrillar protein synthesis irrespective of the lean body mass of the individual [51]. Thus, the consumption of 40 g of protein as a post-match serving seems to enhance protein synthesis rates relative to smaller doses examined previously [52, 53].

Ultimately, protein-requirements should be achieved through high quality protein meals and snacks in the diet (see Table 2). However, appetite can sometimes be suppressed following high intensity exercise so liquid supplements can be provided as an alternative for players who cannot eat solid foods. In this respect, whey protein has proven to be a superior source in comparison to soy or casein when taken in isocaloric amounts [54]. This is due to its quicker digestive properties and rapid absorption kinetics. It also contains a high proportion of the key amino acid leucine, which is believed to be the main

Table 3 Practical nutritional recovery strategies for elite soccer players when limited time separates repeated matches

Phase	Rationale	Practical application
Refuelling (post match) / Pre-Loading (pre match)	<p>A player should aim to consume approximately 6–10 g·kg⁻¹ of body mass (e.g. 480–800 g for an 80 kg player) of carbohydrates on the days where both muscle recovery/loading is needed (24–72 h between games). This should be coupled with a reduction in training volume/intensity.</p> <p>This is to be achieved through 3–4 main meals and regular carbohydrate snacking spaced out throughout the day.</p> <p>Fuel intake should match the demands of energy expended. Players who have been an unused sub or only played part of a game do not require the same level of energy intake as players who played the whole game. Taking in more energy than required could lead to weight gain.</p>	<ul style="list-style-type: none"> • Carbohydrate sources to include as part of a nutritious meal: • Grains (quinoa, pasta, rice, noodles and couscous) • Starchy vegetables (potatoes), Legumes (beans and lentils), Fruits • Cereals (porridge, muesli) • Label foods appropriately to nudge players to increase carbohydrate portion for both match day –1 as well as post-match • Convenient food such as sweet potato wedges, chicken coated in breadcrumbs, and chicken burritos served post-match can increase uptake due to convenience
Maintenance of Repair and Adaptation Daily intake post match before subsequent fixture	<p>During intensified periods of competition a recommended strategy of 1.5 g·kg⁻¹–2 g·kg⁻¹ body weight per day (e.g. 120–160 g for 80 kg player) should be sufficient to fully repair damaged muscle and stimulate soccer specific adaptation.</p> <p>Meals and snacks should be divided into 6 × 20–25 g protein servings over the day, interspersed by roughly 3 h to fully maximise protein synthesis rates in the days between competition.</p>	<p>Protein sources containing 10 g protein (add to carbohydrate sources for high quality recovery meals):</p> <ul style="list-style-type: none"> • 40 g of cooked chicken, lean beef, lamb or pork. • 300 ml milk • 2 small eggs • 30 g of reduced fat cheese • 120 g tofu or soy meat • 50 g canned tuna or salmon or grilled fish
Rehydration Immediate Recovery	<p>Rehydration should occur as soon after exercise finishes. A player should aim to intake a volume that is approximately 150–200% of the estimated deficit to account of ongoing losses (e.g. urine output) with a rough guide of 1 kg weight lost = 1.5 l of fluid required.</p> <p>They should aim to replace the volume lost within 2–4 h post exercise over regular time period to prevent the gastrointestinal distress associated with large fluid intakes.</p> <p>Key electrolytes need to be replaced – principally sodium – and this can be achieved either through electrolyte containing drinks or consuming fluids with 'salty' foods.</p> <p>Excessive alcohol consumption must be avoided as it is counterproductive to overall recovery goals.</p>	<p>Ultimately fluid choices need to be palatable, suit the other recovery needs of the player, practiced and are practical within their recovery environment:</p> <ul style="list-style-type: none"> • Sports drinks containing electrolytes and carbohydrate • Milk based drinks/supplements which include other nutrients • Fruit juices • Cola drinks, tea and coffee could provide a valuable source of fluid and should not be totally avoided • Only have water if salty snacks are consumed at the same time
Reduce inflammation and muscle soreness Immediate Recovery	<p>During intensified fixture congestion antioxidants and anti-inflammatory food components or supplements can modulate the inflammatory reaction may prove beneficial in the acute recovery phase.</p> <p>Concentrated tart cherry juice and omega-3 fish oil supplements are two supplements which may have accelerate recovery time but further research is warranted in elite team sports.</p> <p>It is important to note that any form of antioxidant or anti-inflammatory supplement should be carefully dosed. Soccer-specific adaptations are triggered by the inflammatory and redox reactions occurring after a strenuous exercise stimulus.</p>	<p>Dietary sources of antioxidants include the majority of fruits and vegetables. High antioxidant containing foods for example:</p> <ul style="list-style-type: none"> • Blueberries, Prunes, Blueberries, Sprouts, Broccoli, Raspberry, Sweet cherry <p>Dietary sources contain omega –3:</p> <ul style="list-style-type: none"> • Oily fish, beans, Flax seeds, Walnuts

trigger for muscle protein synthesis augmentation [55]. Animal proteins such as chicken, beef and fish can also contain a high amount of this key amino acid.

Using protein supplements can be a convenient strategy for many athletes. As previously discussed, whey protein

is superior to soy and casein sources because of its rapid digestion and higher leucine content [54]. That said, plasma aminoacidemia is higher following the ingestion of liquid versus solid protein sources [56]; therefore, post-game benefits of fluid-based protein ingestion may

be realised. A ready to drink formulation may also have a greater practical appeal to players post-game.

Leucine is an essential amino acid which through the activation of mammalian target of rapamycin complex (mTOR) signalling pathway may in part attenuate the decrease in muscle protein synthesis after exercise [57]. It is present in high quality proteins and it has been reported that 3 g of leucine is capable of enhancing muscle resistance to insulin through muscle protein synthesis activation [58]. This amount can be obtained through dietary sources such as 140 g of chicken, 170 g of fish or 20–25 g of whey protein, but it can also be ingested as an isolated supplement.

Repair and adaptation after a match - daily recovery between games

After the initial intake of protein in the hours after a game, it is important for the player to continue maximising their protein synthesis over subsequent days to support recovery and adaptation. Players should be strongly encouraged to include sources of protein in their meals with the amount of protein required daily being dependent on the severity of the player's physical programme. Although a sedentary male is recommended to consume $0.8\text{--}1.2\text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ of protein to achieve nitrogen balance, elite soccer players will require more to support their intensified workload during busy periods. For example, a daily protein intake in the range of $2.3\text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ body mass (BM) has shown to better maintain muscle mass when there is an energy deficit [59]. Furthermore, when protein intake was elevated from $1.5\text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ to $3\text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ immune function was better preserved, resulting in less upper respiratory tract infections and an overall tolerance of strenuous training [60].

Although there is an absence in research relating to daily protein intake for elite players during intensified periods, it would be prudent to recommend that at least $1.5\text{--}2\text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ of body mass of protein is consumed in order to cope with demands of a congested fixture period. In order to achieve this amount, an 80 kg player would require approximately 120–160 g of protein per day. Good quality of protein sources such as meat and fish contain around 25 g per 100 g and other sources such as milk, nuts, yoghurt, and beans can contribute to this amount. It has been reported that in elite academy players (U18 s) that there is a skewed distribution of protein intake where more protein is consumed for dinner ($\sim 0.6\text{ g}\cdot\text{kg}^{-1}$) and lunch ($\sim 0.5\text{ g}\cdot\text{kg}^{-1}$) in comparison to breakfast ($\sim 0.3\text{ g}\cdot\text{kg}^{-1}$) [61]. Thus, in terms of the amount of protein consumed over the day, meals or snacks should be divided into $6 \times 20\text{--}25\text{ g}$ (120–150 g of protein) feedings interspersed by 3 h for stimulating maximal protein synthesis throughout a 24 h period [62].

Rehydration after a match – The immediate recovery phase

Intense exercise during a game leads to an increase in metabolic heat production which can raise muscle and rectal temperature to above 39°C [63]. The main physiological mechanism to lose heat from the body is to evaporate sweat on the skin surface, with losses of 2 L even observed in lower ambient temperatures [64]. As a consequence of this level of fluid loss, a player will become dehydrated. For example, a 75 kg player with sweat losses of $>2\text{ L}$ will become dehydrated by $>2\%$. Individual sweat rates can range from 1.1 L to 3.1 L per 90 min [65], outlining the importance of player awareness of their own sweat rate and to rehydrate accordingly post-exercise.

Immediately post-exercise is a period where rehydration strategies should be implemented in order to replace the volume and composition of important fluids lost through sweat. Without adequate rehydration, negative effects on glycogen restoration and protein synthesis rates [66], sprint capacity [67], and subsequent dribbling performance [68] could prevail. It has been reported that at least 150% of the fluid lost during exercise should be consumed to account for a negative fluid balance and urine fluid losses [69]. In practical terms, for every 1 kg of weight lost during exercise would equate to 1.5 L of fluid required post training and this can be monitored through pre-post weighing by support staff.

Time taken to rehydrate is shorter than repletion of muscle glycogen stores (up to 6 h compared to 48–72 h) as long as sufficient fluid and electrolytes are consumed. Although, rehydration may take less time than glycogen re-synthesis, it should be noted that during periods of fixture congestion, especially where teams are playing back to back away fixtures where significant travel is required, it is important to educate players how best to re-hydrate during travel. Moreover, it is not unusual for teams to train 24 h after a match as well as 24 h before a match, placing even greater emphasis on rehydration. Moreover, players should be encouraged to take on adequate fluids during half-time (i.e. 200–300 mL) and throughout the match when opportunities such as a break in play are apparent, to maintain hydration. This is especially important during hot and humid weather conditions.

Sodium is a key electrolyte that should be replaced for optimum fluid restoration. There is a variation amongst players in terms of sodium lost during a game with a reported loss of 10 g of sodium chloride observed during a 90 min soccer session [70]. The consumption of a high sodium drink containing 61 mmol of sodium in volumes equivalent to 150–200% of sweat loss was sufficient to establish a state of hyperhydration 6 h after ingestion [71]. The optimal sodium level during rehydration could be as high as $50\text{--}80\text{ mmol}\cdot\text{L}^{-1}$ which exceeds the amounts found in a typical sports drink [72]. Water is an electrolyte free drink and is not ideal for rehydration post-exercise as

a rapid reduction in plasma sodium concentration could ensure which subsequently increases urine output [73]. Therefore, drinks for rehydration should have high electrolyte content (i.e. 40 or 50 mmol·L⁻¹ of sodium chloride) and consist of carbohydrate sources to increase palatability [74] and help with glycogen restoration. In this respect, sports drinks are superior to water for fluid restoration due to their provision of both carbohydrate and electrolytes.

Team sports such as soccer can be associated with a moderate to high post-match alcohol intake to celebrate or commiserate over the game result; especially in the amateur game. Although this practice is slowly diminishing at the elite level, alcohol consumption can negatively affect a player's ability to recover especially when consumed during periods of fixture congestion [75]. More specifically, alcohol has recently been shown to reduce myofibrillar protein synthesis rates even if coingested with protein, resulting in an impairment of recovery and adaptation from exercise by suppressing skeletal muscle anabolic responses [75]. Moreover, alcohol consumed after a match can also exacerbate dehydration especially when consumed during the recovery period several hours after a match [76]. Thus it is prudent to educate players regarding the negative effects of alcohol on recovery when multiple matches are played within a short period of time.

Overnight recovery following match-play

Recovery nutrition towards the end of a day during periods of fixture congestion as well as intensive training is often overlooked by athletes. For instance, protein ingested before sleep has proven to be effectively digested and absorbed, leading to an increase in protein synthesis and improving whole-body protein balance during overnight recovery [49]. Ingesting a pre-sleep protein snack high in casein such as 200 g of cottage cheese or alternatively, a formulated protein supplement containing 40 g of casein protein will likely prove beneficial for increasing the time in a net-positive anabolic state over the course of a day [77]. This is due to its slow release properties over a prolonged sleeping period. The absence of this pre-sleep feed will not improve overnight protein balance; possibly compromising muscle protein synthesis rates over the 24 h period. A summary of the recovery nutrition guidelines have been summarised in Table 3.

Supplements and recovery

Fundamentally, macro and micro nutrients should come primarily from food sources in the diet; however, players may require a constituent, metabolite, concentrate or extract in isolation that is difficult to source in quantities required from food [78]. While energy consumption from supplements in professional soccer has not been studied, it has been reported that in professional Rugby League

players approximately 16% of energy intake came from the use of supplements such as pre-exercise energy drinks, carbohydrate drinks, and recovery drinks [79]. It is important to emphasise that supplements should be consumed to 'supplement' a healthy diet and not to replace it. Moreover, elite players should be cautious with supplements and only take batch tested products that have been tested for banned substances. Specific guidelines have yet to be developed with limited research available for the use of some supplements, especially in the context of recovery from elite soccer match-play during periods of fixture congestion. Nevertheless, supplement use during this short recovery phase has become common practice in soccer clubs across a range of ages. Immediately after a match and several hours afterwards, feeding a team with nutritious food can be problematic and therefore certain supplements can be convenient to enhance recovery. A brief review of popular products is provided in this section with reference to their application for recovery.

Carbohydrate and protein supplements

Carbohydrate and protein supplements can be both useful and practical for players to enhance recovery during periods of fixture congestion. We have previously discussed both the importance and practical application of carbohydrate and protein supplements under the "recovery nutrition strategies" section.

Creatine

During repeated soccer-specific actions phosphocreatine stores diminish significantly as a consequence of adenosine triphosphate regeneration through phosphocreatine hydrolysis in the initial seconds of supra-maximal activity [80]. To increase resting muscle phosphocreatine stores quickly, a creatine loading protocol can be used with the conventional strategy involving 4 × 5 g doses of creatine supplementation per day for 5–7 days proceeded by a maintenance dose of 3–5 g per day [81]. However, a lower daily dose of ~3 g per day for 28 days will result in a similar increase in phosphocreatine stores [81] to the loading protocol. It has been reported that muscle glycogen resynthesis can be enhanced following creatine loading [82]. Practically, creatine can be added to the post-match and post-training recovery drink and it may prove beneficial in optimising refuelling strategies especially during congested fixture schedules.

In agreement with data from the general population [83], empirical observations highlight that sleep deprivation is common on the night(s) prior to sporting competition; especially, if matches require prior international air travel. Interestingly, players who self-reported 7–9 h sleep on the night before testing outperformed their sleep-deprived counterparts (i.e., those reporting 3–5 h sleep) by ~20% in a rugby passing task [84]. Such differences were

ameliorated when creatine (50 or 100 mg·kg⁻¹) or caffeine (1 or 5 mg·kg⁻¹) was provided to sleep-deprived players 90 min before skill testing commenced; a response attributed to the attenuation of sleep-deprivation induced reductions in brain phosphocreatine concentrations and the stimulatory effects of adenosine-receptors, respectively [84].

Caffeine

There is some evidence that large amounts of caffeine taken with carbohydrate can enhance glycogen resynthesis post-exercise [85, 86]. Pederson and colleagues [85] found that co-ingestion of carbohydrate and caffeine (4 g·kg⁻¹ and 8 mg·kg⁻¹, respectively) resulted in greater glycogen resynthesis compared to 4 g·kg⁻¹ of body mass of carbohydrate only. Muscle biopsy data showed that although no differences were observed in glycogen resynthesis after 1 h post-exercise (133–37.8 vs. 149–48 mmol·kg⁻¹ dry weight; for carbohydrate and caffeine, respectively), after 4 h of recovery the caffeine condition resulted in a 66% higher glycogen accumulation (313–69 vs. 234–50 mmol/kg dry weight; $p < 0.001$). Similarly, Taylor et al. [86] found that co-ingestion of carbohydrate and caffeine (1.2 g·kg⁻¹ and 8 mg·kg⁻¹, respectively) resulted in an increased time to exhaustion on the Loughborough Intermittent Shuttle Test compared with the carbohydrate only and water condition. Although Taylor et al. [86] did not take any muscle biopsy data to measure glycogen resynthesis, the authors concluded that adding 8 mg·kg⁻¹ of caffeine to a post-exercise carbohydrate drink improved subsequent high-intensity interval-running capacity, a finding that may be related to higher rates of post-exercise muscle glycogen resynthesis. Whilst the findings of Pedersen et al. [85] and Taylor et al. [86] may be useful for recovery, as they suggest that adding large doses of caffeine to carbohydrate post-exercise can enhance glycogen resynthesis, this strategy may not always be practical, particularly when matches kick off either late afternoon or evening as this strategy will compromise sleep. Nonetheless, this strategy could be employed for matches that have early kick off times.

Antioxidants and polyphenols

When time is limited between games, dietary components that modulate the inflammatory process may prove beneficial in the acute recovery phase. However, it is important to note that any form of antioxidant or anti-inflammatory supplement should be carefully dosed. Soccer-specific adaptations are triggered by the inflammatory and redox reactions occurring after a strenuous exercise stimulus. Therefore, chronically high doses in their provision are likely to be detrimental to the long term training effect [87]. For example, large doses of vitamins C and E have proven to have detrimental effects to cellular adaptation [88, 89]. Strategic use of anti-inflammatory and

antioxidant foods/supplements in and around periods of heavy training/game scheduling is the best approach for optimal recovery, rather than chronic daily use.

Antioxidant- and polyphenol-rich foods such as cherry and pomegranate juice have been found to enhance recovery following heavy training [90–94]. For example, 0.682 L a day of tart cherry juice consumption before and after eccentric exercise significantly reduced symptoms of muscle damage [95]. Similarly, Montmorency cherry juice has also been shown to enhance recovery following prolonged, repeat sprint activity in semi-professional male soccer players [91]. In addition, 500 mL of pomegranate juice has been shown to reduce DOMS after strenuous exercise [92, 94]. However, these findings should be interpreted with some caution as participants were fasted and restricted polyphenol based foods beforehand. Theaflavin-enriched black tea extract supplementation in doses of 1760 mg daily for nine days has also been found to enhance recovery, reduce oxidative stress reduce muscle soreness in response to acute anaerobic intervals [96]. Thus, the potential beneficial effects of antioxidants and polyphenols to accelerate recovery are encouraging but more research is warranted using protocols which demonstrate greater ecological validity, especially in relation to soccer specific activity. Nevertheless, in situations where players have back-to-back matches with little time for recovery or in tournament situations where adaptation to training is likely not a key priority, certain antioxidant supplements and polyphenol-rich foods may be beneficial for recovery but chronic use should be avoided.

Omega-3 supplementation

Omega-3 is found naturally in oily fish such as salmon, mackerel and sardines, and in a more concentrated form as a fish oil supplement. Fish oil supplements contain the long chain polyunsaturated omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). It should be noted that the research on Omega-3 fatty acid supplements is conflicting as some studies show beneficial effects on reducing inflammation [97] and delayed onset muscle soreness [98–100], whereas, other show no benefit [101, 102]. Phillips and colleagues [97] found that fish oil supplementation reduced exercise-induced inflammation. Similarly, other studies have found that 1.8 g [98], 2.7 g [100], and 3 g [99] of Omega-3 fatty acid supplementation reduced DOMS after exercise. In contrast, other studies have found a reduction in oxidative stress following exercise with fish oil supplementation but no difference in DOMS [102] and further studies have no effect on DOMS [101]. Despite the inconsistencies regarding fish oil supplementation, there does seem to be some evidence for using Omega-3 fatty acid supplementation in doses of 1.8 to 3 g per day to

reduce inflammation and muscle soreness after matches, especially during periods of fixture congestion.

Practical considerations in elite soccer

Fixture scheduling possibly provides the biggest challenge to recovery in elite soccer. It is not unusual for top teams to have 3 games in a 10 day period in 3 different locations (see Fig. 1). The timing of kick offs in these games varies from week to week as a consequence of increased television coverage. For example, a team could play a home match at 15:00 h on a Saturday, travel to Europe to play an away match on Wednesday night at 19:45 h and return to play another away match at 12:45 h on the subsequent Saturday. It is these types of scenarios where recovery strategies take on extra significance. The selection of foods and timing of intake in and around travel are critical factors for optimal recovery. An example of recovery nutrition timeline after a match is shown in Fig. 2. Support staff cannot always rely on external catering thus some foods need to be portable to away games without compromising on quality and in these situations, teams could take their own chef who can work closely with the sport nutritionist to

devise suitable menus. Moreover, sleep deprivation will become an issue as a result of late games so timing of recovery nutrition to optimise sleep quality is of significance and this has been reviewed elsewhere [103].

It is easy to formulate a recovery nutrition strategy on paper but implementing it effectively and attaining player adherence in the elite environment can prove a difficult proposition. The role of a sports nutritionist and/or sport science practitioner is to implement these recovery principles by adapting to certain practical restraints (see Table 4 for some practical issues and solutions). The practitioner has to keep in mind that devotion to the right strategies can optimise a player's physical performance and reduce the risk of fatigue-related injury. This is particularly imperative during a period of congested fixtures where recovery time between matches is limited.

At the elite level there is a mix of different cultures and nationalities within a team dressing room but without an empathy and understanding of this environment a player's match performance and adaptation to exercise can suffer if recovery nutrition is inadequate. To counteract this, a potential strategy could be to introduce a different international theme to recovery snacks/foods at certain points

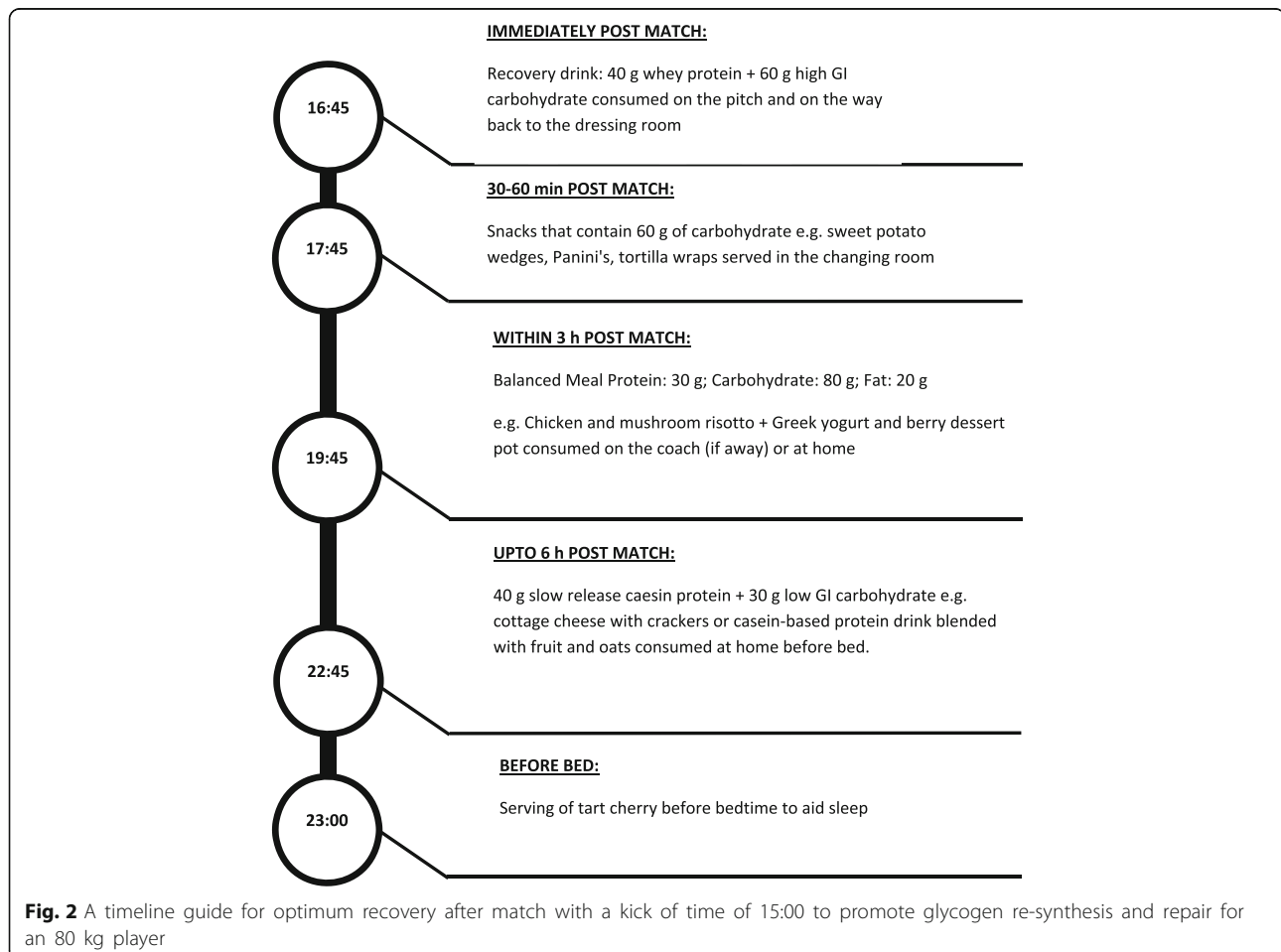


Table 4 Practical issues that interfere with post-match recovery nutrition and solutions to counteract these concerns

Practical Issue	Practical Solution
Players within a team who are uneducated and have a detrimental habit of poor quality nutrients during recovery	Educate the team on the importance of recovery nutrition; stressing the beneficial role is had on performance and adaptation. Integrating backroom staff (physiotherapists, coaches, doctor) into this education so that they can re-enforce nutrition policies day to day. Use visuals around the training ground to educate players key messages
Night games limit the time consume recovery nutrients before sleep	Ensure that recovery strategies are implemented every hour until sleep, encouraging more liquid based nutrient sources (e.g. milkshakes, sport supplement drink) to offset any potential gastrointestinal issues associated with the ingestion of solid foods before bed. No caffeinated drinks (e.g. coffee, cola) should be consumed pre-sleep, but a snack containing casein (slow release protein) is important have before bedtime.
Travel to and from away games, sometimes internationally	Recovery snacks need to be carefully chosen so that they are portable and able to travel internationally, without compromising on their quality (e.g. sports bars). Planning is key, ensuring that foods are readily available during transit (e.g. on the team bus or plane). A traveling chef can help enhance quality and taste of meals provided during travel.
Players quickly exiting the stadium to travel home soon after the end of a match (normally in their own car after home games)	Providing a buffet style food selection which provides high-quality sources of mixed carbohydrate and protein snacks. Also, providing a recovery 'pack' which contains recovery snacks and/or supplements along with a timing plan for players who have long to travel home.
Players who have been unused sub or not played any minutes	Monitor the minutes played/exercised at higher intensities for all players in the squad. The energy demands and recovery requirements will vary between each individual and should be adjusted accordingly so body composition issues or an energy deficit do not arise. This can be communicated to players using match data
Loss of appetite following high intensity activity	Liquid based nutrient sources such as milkshake and meal replacement shakes should be encouraged to players who don't have the appetite for food post-match. Again, stress the importance of having recovery nutrition after a game, highlighting the benefits for them as a soccer player (e.g. reduce the risk of injury, improve subsequent performance).
Players choose nutrient-poor foods (i.e. chocolate bar or crisps) because they are more accessible after exercise	Create a culture that promotes good nutrition by using visual displays at the training ground or stadium changing room as well as face to face education. Ensure that a recovery station is set up with high quality food choices (see examples in Table 1) with buffet food selection post game.

throughout the season for player engagement. This will provide an additional food option during recovery without compromising on the quality of nutrients.

For players, it would also be beneficial to set up a recovery station and buffet style food selection in the changing room after the game which incorporates high-quality sources of carbohydrate and protein recovery snacks. This strategy will ensure that recovery nutrition is readily available after a game before they travel home. It is common practice for some players to quickly exit a game/training almost immediately after exercise so it is important to have this option available. If this option is avoided, a recovery 'pack' which contains recovery snacks and/or supplements along with a timing plan could be provided for any players who request; particularly encouraging those who have a long way to travel home and won't have access to foods.

Support staff may also want to consider an individualised approach to recovery nutrition based on player position. With modern technology such as Global Positioning System (GPS) and data obtained from match analysis such as total distance and high

intensity distance covered, recovery strategies could be individualised. For example, players working at higher intensities (typically the full backs, and attacking midfielders) would increase the amount of carbohydrate within the immediate recovery phase. Whereas, the goalkeepers would follow lower carbohydrate diet in order to match the lower energy expenditures.

Conclusion

The growing match play and training demands of a professional soccer player are putting a greater emphasis on the role of nutritional recovery in regaining performance and reducing the risk of injury. Certain dietary practices should commence immediately after a competitive game or high intensity training session before the opportunity to fully optimise the recuperation process diminishes. Carbohydrate replenishment should take precedence to replace the fuel lost to perform high intensity work with protein consumption playing an important role in muscle repair and rehydration aiding the overall recovery process. Daily strategies incorporating

these key nutrients should become common practice on subsequent recovery days between fixtures, especially during congestive weeks. Antioxidants and other nutrients can have a modulating role of the inflammatory process during these busy periods but their use needs be strategic rather than chronic to ensure adaptations to training are not blunted. Current practical issues are ever present in an elite environment and need to be counteracted to achieve success in nutritional approach.

Acknowledgements

Not applicable.

Funding

No funding sources were received for the preparation of this manuscript.

Availability of data and materials

Not applicable

Authors' contributions

JTD came up with the idea for the manuscript. MKR and JTD wrote the article. MR edited the article and provided valuable comments to enhance the review. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details

¹Sheffield Hallam University, Academy of Sport & Physical Activity, A220 Collegiate Hall, Collegiate Crescent Campus, Sheffield S102BP, UK. ²Stoke City Football Club, bet365 Stadium, Stanley Matthews Way, Stoke-on-Trent ST4 4EG, UK. ³School of Social and Health Sciences, Leeds Trinity University, Horsforth, Leeds LS18 5HD, UK.

Received: 21 February 2017 Accepted: 5 September 2017

Published online: 12 September 2017

References

- Lago-Peñas C, Rey E, Lago-Ballesteros J, Casáis L, Domínguez E. The influence of a congested calendar on physical performance in elite soccer. *J Strength Cond Res*. 2011;25(8):2111–7.
- Carling C, Le Gall F, Dupont G. Are physical performance and injury risk in a professional soccer team in match-play affected over a prolonged period of fixture congestion? *Int J Sports Med*. 2012;33(01):36–42.
- Nedelec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer: part I - post-match fatigue and time course of recovery. *Sports Med*. 2012 Dec 1;42(12):997–1015.
- McCall A, Davison M, Andersen TE, Beasley I, Bizzini M, Dupont G, et al. Injury prevention strategies at the FIFA 2014 world cup: perceptions and practices of the physicians from the 32 participating national teams. *Br J Sports Med*. 2015 May;49(9):603–8.
- Dupont G, Nedelec M, McCall A, McCormack D, Berthoin S, Wisloff U. Effect of 2 soccer matches in a week on physical performance and injury rate. *Am J Sports Med*. 2010 Sep;38(9):1752–8.
- Ekstrand J, Hagglund M, Walden M. Epidemiology of muscle injuries in professional football (soccer). *Am J Sports Med*. 2011 Jun;39(6):1226–32.
- Carling C, McCall A, Le Gall F, Dupont G. The impact of short periods of match congestion on injury risk and patterns in an elite football club. *Br J Sports Med*. 2016 Jun;50(12):764–8.
- Mohr M, Draganidis D, Chatzinikolaou A, Barbero-Álvarez JC, Castagna C, Douroudos I, et al. Muscle damage, inflammatory, immune and performance responses to three football games in 1 week in competitive male players. *Eur J Appl Physiol*. 2016;116(1):179–93.
- Carling C, McCall A, Le Gall F, Dupont G. What is the extent of exposure to periods of match congestion in professional soccer players? *J Sports Sci*. 2015;33(20):2116–24.
- Nédélec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer. *Sports Med*. 2013;43(1):9–22.
- Bangsbo J, Mohr M, Krstrup P. Physical and metabolic demands of training and match-play in the elite football player. *J Sports Sci*. 2006 Jul;24(7):665–74.
- Mohr M, Krstrup P, Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *J Sports Sci*. 2003 Jul;21(7):519–28.
- Russell M, Sparkes W, Northeast J, Kilduff LP. Responses to a 120 min reserve team soccer match: a case study focusing on the demands of extra time. *J Sports Sci*. 2015;33(20):2133–9.
- Harper LD, West DJ, Stevenson E, Russell M. Technical performance reduces during the extra-time period of professional soccer match-play. *PLoS One*. 2014;9(10):e110995.
- Osgnach C, Poser S, Bernardini R, Rinaldo R, Di Prampero PE. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc*. 2010;42(1):170–8.
- Rico-Sanz J, Frontera WR, Mole PA, Rivera MA, Rivera-Brown A, Meredith CN. Dietary and performance assessment of elite soccer players during a period of intense training. *Int J Sport Nutr*. 1998 Sep;8(3):230–40.
- Ebine N, Rafamantanantsoa HH, Nayuki Y, Yamanaka K, Tashima K, Ono T, et al. Measurement of total energy expenditure by the doubly labelled water method in professional soccer players. *J Sports Sci*. 2002;20(5):391–7.
- Anderson L, Orme P, Naughton RJ, Close GL, Milsom J, Rydings D, et al. Energy intake and expenditure of professional soccer players of the English premier league: evidence of carbohydrate periodization. *Int J Sport Nutr Exerc Metab*. 2017;1–25.
- Briggs MA, Cockburn E, Rumbold PL, Rae G, Stevenson EJ, Russell M. Assessment of energy intake and energy expenditure of male adolescent academy-level soccer players during a competitive week. *Nutrients*. 2015; 7(10):8392–401.
- Russell M, Pennock A. Dietary analysis of young professional soccer players for 1 week during the competitive season. *J Strength Cond Res*. 2011 Jul; 25(7):1816–23.
- Loucks AB, Kiens B, Wright HH. Energy availability in athletes. *J Sports Sci*. 2011;29(Suppl 1):S7–15.
- Ranchordas MK, Bannock L, Robinson SL. Case Study: Nutritional and Lifestyle Support to Reduce Infection Incidence in an International-Standard Premier League Soccer Player. *Int J Sport Nutr Exerc Metab*. 2016;26(2):185–91.
- Bangsbo J. Energy demands in competitive soccer. *J Sports Sci*. 1994 Summer;12 Spec No:55–12.
- Saltin B. Metabolic fundamentals in exercise. *Med Sci Sports*. 1973;5(3):137–46.
- Gunnarsson TP, Bendiksen M, Bischoff R, Christensen PM, Lesivig B, Madsen K, et al. Effect of whey protein- and carbohydrate-enriched diet on glycogen resynthesis during the first 48 h after a soccer game. *Scand J Med Sci Sports*. 2013 Aug;23(4):508–15.
- Rampinini E, Bosio A, Ferraresi I, Petruolo A, Morelli A, Sassi A. Match-related fatigue in soccer players. *Med Sci Sports Exerc*. 2011 Nov;43(11):2161–70.
- Howatson G, Milak A. Exercise-induced muscle damage following a bout of sport specific repeated sprints. *J Strength Cond Res*. 2009 Nov;23(8):2419–24.
- Ivy JL, Katz AL, Cutler CL, Sherman WM, Coyle EF. Muscle glycogen synthesis after exercise: effect of time of carbohydrate ingestion. *J Appl Physiol* (1985). 1988 Apr;64(4):1480–5.
- Burke LM, Kiens B, Ivy JL. Carbohydrates and fat for training and recovery. *J Sports Sci*. 2004 Jan;22(1):15–30.
- van Loon LJ, Kruijschoop M, Verhagen H, Saris WH, Wagenmakers AJ. Ingestion of protein hydrolysate and amino acid-carbohydrate mixtures increases postexercise plasma insulin responses in men. *J Nutr*. 2000 Oct; 130(10):2508–13.
- Ivy JL, Goforth HW Jr, Damon BM, McCauley TR, Parsons EC, Price TB. Early postexercise muscle glycogen recovery is enhanced with a carbohydrate-protein supplement. *J Appl Physiol* (1985). 2002 Oct;93(4):1337–44.

32. Kien B, Raben A, Valeur A, Richter E. Benefits of dietary simple carbohydrate on the early post exercise muscle glycogen repletion. *Med Sci Sport*. 1990; 22:S88–96.
33. Jentjens R, Jeukendrup AE. Determinants of post-exercise glycogen synthesis during short-term recovery. *Sports Med*. 2003;33(2):117–44.
34. Burke LM, Collier GR, Hargreaves M. Glycemic index—a new tool in sport nutrition? *Int J Sport Nutr*. 1998;8(4):401–15.
35. Burke LM, Collier GR, Hargreaves M. Muscle glycogen storage after prolonged exercise: effect of the glycemic index of carbohydrate feedings. *J Appl Physiol* (1985). 1993 Aug;75(2):1019–23.
36. Erith S, Williams C, Stevenson E, Chamberlain S, Crews P, Rushbury I. The effect of high carbohydrate meals with different glycemic indices on recovery of performance during prolonged intermittent high-intensity shuttle running. *Int J Sport Nutr Exerc Metab*. 2006 Aug;16(4):393–404.
37. Keizer HA, Kuipers H, van Kranenburg G, Geurten P. Influence of liquid and solid meals on muscle glycogen resynthesis, plasma fuel hormone response, and maximal physical working capacity. *Int J Sports Med*. 1987 Apr;8(2):99–104.
38. Jeukendrup AE. Carbohydrate intake during exercise and performance. *Nutrition*. 2004 Jul-Aug;20(7–8):669–77.
39. Jeukendrup A, Moseley L. Multiple transportable carbohydrates enhance gastric emptying and fluid delivery. *Scand J Med Sci Sports*. 2010;20(1):112–21.
40. Jeukendrup AE. Carbohydrate and exercise performance: the role of multiple transportable carbohydrates. *Curr Opin Clin Nutr Metab Care*. 2010 Jul;13(4):452–7.
41. van Loon LJ. Application of protein or protein hydrolysates to improve postexercise recovery. *Int J Sport Nutr Exerc Metab*. 2007 Aug;17(Suppl):S104–17.
42. Beck KL, Thomson JS, Swift RJ, von Hurst PR. Role of nutrition in performance enhancement and postexercise recovery. *Open Access J Sports Med*. 2015 Aug 11;6:259–67.
43. Pritchett K, Pritchett R. Chocolate milk: a post-exercise recovery beverage for endurance sports. *Med Sport Sci*. 2012;59:127–34.
44. Saunders MJ. Carbohydrate-protein intake and recovery from endurance exercise: is chocolate milk the answer? *Curr Sports Med Rep*. 2011 Jul;10(4):203–10.
45. Burke LM. Fueling strategies to optimize performance: training high or training low? *Scand J Med Sci Sports*. 2010 Oct;20(Suppl 2):48–58.
46. Nicholas CW, Green PA, Hawkins RD, Williams C. Carbohydrate intake and recovery of intermittent running capacity. *Int J Sport Nutr*. 1997 Dec; 7(4):251–60.
47. Krstrup P, Ortenblad N, Nielsen J, Nybo L, Gunnarsson TP, Iaia FM, et al. Maximal voluntary contraction force, SR function and glycogen resynthesis during the first 72 h after a high-level competitive soccer game. *Eur J Appl Physiol*. 2011 Dec;111(12):2987–95.
48. Costill DL, Pascoe DD, Fink WJ, Robergs RA, Barr SI, Pearson D. Impaired muscle glycogen resynthesis after eccentric exercise. *J Appl Physiol* (1985). 1990 Jul;69(1):46–50.
49. Beelen M, Burke LM, Gibala MJ, van Loon LJC. Nutritional strategies to promote postexercise recovery. *Int J Sport Nutr Exerc Metab*. 2010 Dec; 20(6):515–32.
50. Silva JR, Ascensão A, Marques F, Seabra A, Rebelo A, Magalhães J. Neuromuscular function, hormonal and redox status and muscle damage of professional soccer players after a high-level competitive match. *Eur J Appl Physiol*. 2013;113(9):2193–201.
51. Macnaughton LS, Wardle SL, Witard OC, McGlory C, Hamilton DL, Jeromson S, et al. The response of muscle protein synthesis following whole-body resistance exercise is greater following 40 g than 20 g of ingested whey protein. *Physiol Rep*. 2016 Aug;4(15) 10.14814/phy.2.12893.
52. Witard OC, Jackman SR, Breen L, Smith K, Selby A, Tipton KD. Myofibrillar muscle protein synthesis rates subsequent to a meal in response to increasing doses of whey protein at rest and after resistance exercise. *Am J Clin Nutr*. 2014 Jan;99(1):86–95.
53. Moore DR, Robinson MJ, Fry JL, Tang JE, Glover EI, Wilkinson SB, et al. Ingested protein dose response of muscle and albumin protein synthesis after resistance exercise in young men. *Am J Clin Nutr*. 2009 Jan;89(1):161–8.
54. Tang JE, Moore DR, Kujbida GW, Tarnopolsky MA, Phillips SM. Ingestion of whey hydrolysate, casein, or soy protein isolate: effects on mixed muscle protein synthesis at rest and following resistance exercise in young men. *J Appl Physiol* (1985). 2009 Sep;107(3):987–92.
55. Garlick PJ. The role of leucine in the regulation of protein metabolism. *J Nutr*. 2005 Jun;135(6 Suppl):1553S–6S.
56. Burke LM, Winter JA, Cameron-Smith D, Enslen M, Farnfield M, Decombaz J. Effect of intake of different dietary protein sources on plasma amino acid profiles at rest and after exercise. *Int J Sport Nutr Exerc Metab*. 2012; 22(6):452–62.
57. van Loon LJ. Leucine as a pharmacutrient in health and disease. *Curr Opin Clin Nutr Metab Care*. 2012 Jan;15(1):71–7.
58. Katsanos CS, Kobayashi H, Sheffield-Moore M, Aarsland A, Wolfe RR. A high proportion of leucine is required for optimal stimulation of the rate of muscle protein synthesis by essential amino acids in the elderly. *Am J Physiol Endocrinol Metab*. 2006 Aug;291(2):E381–7.
59. Mettler S, Mitchell N, Tipton KD. Increased protein intake reduces lean body mass loss during weight loss in athletes. *Med Sci Sports Exerc*. 2010 Feb; 42(2):326–37.
60. Witard OC, Jackman SR, Kies AK, Jeukendrup AE, Tipton KD. Effect of increased dietary protein on tolerance to intensified training. *Med Sci Sports Exerc*. 2011 Apr;43(4):598–607.
61. Naughton RJ, Drust B, O'Boyle A, Morgans R, Abayomi J, Davies IG, et al. Daily distribution of carbohydrate, protein and fat intake in elite youth academy soccer players over a 7-day training period. *Int J Sport Nutr Exerc Metab*. 2016;26(5):473–80.
62. Areta JL, Burke LM, Ross ML, Camera DM, West DW, Broad EM, et al. Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *J Physiol*. 2013 May 1;591(Pt 9):2319–31.
63. Mohr M, Krstrup P, Nybo L, Nielsen JJ, Bangsbo J. Muscle temperature and sprint performance during soccer matches—beneficial effect of re-warm-up at half-time. *Scand J Med Sci Sports*. 2004 Jun;14(3):156–62.
64. Maughan RJ, Watson P, Evans GH, Broad N, Shirreffs SM. Water balance and salt losses in competitive football. *Int J Sport Nutr Exerc Metab*. 2007 Dec; 17(6):583–94.
65. Shirreffs SM, Sawka MN, Stone M. Water and electrolyte needs for football training and match-play. *J Sports Sci*. 2006 Jul;24(7):699–707.
66. Gonzalez-Alonso J. Hyperthermia impairs brain, heart and muscle function in exercising humans. *Sports Med*. 2007;37(4–5):371–3.
67. Mohr M, Mujika I, Santisteban J, Randers MB, Bischoff R, Solano R, et al. Examination of fatigue development in elite soccer in a hot environment: a multi-experimental approach. *Scand J Med Sci Sports*. 2010 Oct;20(Suppl 3): 125–32.
68. McGregor SJ, Nicholas CW, Lakomy HK, Williams C. The influence of intermittent high-intensity shuttle running and fluid ingestion on the performance of a soccer skill. *J Sports Sci*. 1999 Nov;17(11):895–903.
69. Shirreffs SM, Maughan RJ. Volume repletion after exercise-induced volume depletion in humans: replacement of water and sodium losses. *Am J Phys*. 1998 May;274(5 Pt 2):F868–75.
70. Maughan RJ, Merson SJ, Broad NP, Shirreffs SM. Fluid and electrolyte intake and loss in elite soccer players during training. *Int J Sport Nutr Exerc Metab*. 2004 Jun;14(3):333–46.
71. Shirreffs SM, Taylor AJ, Leiper JB, Maughan RJ. Post-exercise rehydration in man: effects of volume consumed and drink sodium content. *Med Sci Sports Exerc*. 1996 Oct;28(10):1260–71.
72. Shirreffs SM, Maughan RJ. Whole body sweat collection in humans: an improved method with preliminary data on electrolyte content. *J Appl Physiol* (1985). 1997 Jan;82(1):336–41.
73. Nose H, Mack GW, Shi XR, Nadel ER. Role of osmolality and plasma volume during rehydration in humans. *J Appl Physiol* (1985). 1988 Jul; 65(1):325–31.
74. Shirreffs SM. Restoration of fluid and electrolyte balance after exercise. *Can J Appl Physiol*. 2001;26(Suppl):S228–35.
75. Parr EB, Camera DM, Areta JL, Burke LM, Phillips SM, Hawley JA, et al. Alcohol ingestion impairs maximal post-exercise rates of myofibrillar protein synthesis following a single bout of concurrent training. *PLoS One*. 2014 Feb 12;9(2):e88384.
76. Barnes MJ. Alcohol: impact on sports performance and recovery in male athletes. *Sports Med*. 2014;44(7):909–19.
77. Trommelen J, van Loon LJ. Pre-sleep protein ingestion to improve the skeletal muscle adaptive response to exercise training. *Nutrients*. 2016;8(12):763.
78. Hespel P, Maughan RJ, Greenhaff PL. Dietary supplements for football. *J Sports Sci*. 2006 Jul;24(7):749–61.
79. Tooley E, Bitcon M, Briggs M, West D, Russell M. Estimates of energy intake and expenditure in professional rugby league players. *International Journal of Sports Science & Coaching*. 2015;10(2–3):551–60.

80. Krstrup P, Mohr M, Steensberg A, Bencke J, Kjaer M, Bangsbo J. Muscle and blood metabolites during a soccer game: implications for sprint performance. *Med Sci Sports Exerc.* 2006 Jun;38(6):1165–74.
81. Hultman E, Soderlund K, Timmons JA, Cederblad G, Greenhaff PL. Muscle creatine loading in men. *J Appl Physiol* (1985). 1996 Jul;81(1):232–7.
82. Robinson TM, Sewell DA, Hultman E, Greenhaff PL. Role of submaximal exercise in promoting creatine and glycogen accumulation in human skeletal muscle. *J Appl Physiol* (1985). 1999 Aug;87(2):598–604.
83. Kronholm E, Sallinen M, Suutama T, Sulkava R, Era P, Partonen T. Self-reported sleep duration and cognitive functioning in the general population. *J Sleep Res.* 2009;18(4):436–46.
84. Cook CJ, Crewther BT, Kilduff LP, Drawer S, Gaviglio CM. Skill execution and sleep deprivation: effects of acute caffeine or creatine supplementation—a randomized placebo-controlled trial. *J Int Soc Sports Nutr.* 2011;8(1):2.
85. Pedersen DJ, Lessard SJ, Coffey VG, Churchley EG, Wootton AM, Ng T, et al. High rates of muscle glycogen resynthesis after exhaustive exercise when carbohydrate is coingested with caffeine. *J Appl Physiol* (1985). 2008 Jul;105(1):7–13.
86. Taylor C, Higham D, Close GL, Morton JP. The effect of adding caffeine to postexercise carbohydrate feeding on subsequent high-intensity interval-running capacity compared with carbohydrate alone. *Int J Sport Nutr Exerc Metab.* 2011;21(5):410–6.
87. Baar K. Nutrition and the adaptation to endurance training. *Sports Med.* 2014 May;44(Suppl 1):S5–12.
88. Gomez-Cabrera MC, Pallardo FV, Sastre J, Vina J, Garcia-del-Moral L. Allopurinol and markers of muscle damage among participants in the Tour de France. *JAMA.* 2003 05/21;289(19):2503–2504.
89. Teixeira V, Valente H, Casal S, Marques F, Moreira P. Antioxidant status, oxidative stress, and damage in elite trained kayakers and canoeists and sedentary controls. *Int J Sport Nutr Exerc Metab.* 2009 10;19(5):443–456.
90. Howatson G, McHugh MP, Hill JA, Brouner J, Jewell AP, van Someren KA, et al. Influence of tart cherry juice on indices of recovery following marathon running. *Scand J Med Sci Sports.* 2010 Dec;20(6):843–52.
91. Bell PG, Stevenson E, Davison GW, Howatson G. The effects of Montmorency tart cherry concentrate supplementation on recovery following prolonged, intermittent exercise. *Nutrients.* 2016;8(7):441.
92. Trombold JR, Barnes JN, Critchley L, Coyle EF. Ellagitannin consumption improves strength recovery 2–3 d after eccentric exercise. *Med Sci Sports Exerc.* 2010;42(3):493–8.
93. Connolly DA, Lauzon C, Agnew J, Dunn M, Reed B. The effects of vitamin C supplementation on symptoms of delayed onset muscle soreness. *J Sports Med Phys Fitness.* 2006 09;46(3):462–467.
94. Trombold JR, Reinfeld AS, Casler JR, Coyle EF. The effect of pomegranate juice supplementation on strength and soreness after eccentric exercise. *J Strength Cond Res.* 2011 Jul;25(7):1782–8.
95. Connolly DA, McHugh MP, Padilla-Zakour OI, Carlson L, Sayers SP. Efficacy of a tart cherry juice blend in preventing the symptoms of muscle damage. *Br J Sports Med.* 2006;40(8) 679,83; discussion 683.
96. Arent SM, Senso M, Golem DL, McKeever KH. The effects of theaflavin-enriched black tea extract on muscle soreness, oxidative stress, inflammation, and endocrine responses to acute anaerobic interval training: a randomized, double-blind, crossover study. *J Int Soc Sports Nutr.* 2010;7(1):11.
97. Phillips T, Childs AC, Dreon DM, Phinney S, Leeuwenburgh C. A dietary supplement attenuates IL-6 and CRP after eccentric exercise in untrained males. *Med Sci Sports Exerc.* 2003 Dec;35(12):2032–7.
98. Tartibian B, Maleki BH, Abbasi A. The effects of ingestion of omega-3 fatty acids on perceived pain and external symptoms of delayed onset muscle soreness in untrained men. *Clin J Sport Med.* 2009 Mar;19(2):115–9.
99. Jouris KB, McDaniel JL, Weiss EP. The effect of Omega-3 fatty acid supplementation on the inflammatory response to eccentric strength exercise. *J Sports Sci Med.* 2011 Sep 1;10(3):432–8.
100. Lembke P, Capodice J, Hebert K, Swenson T. Influence of omega-3 (n3) index on performance and wellbeing in young adults after heavy eccentric exercise. *J Sports Sci Med.* 2014 Jan 20;13(1):151–6.
101. Lenn J, Uhl T, Mattacola C, Boissonneault G, Yates J, Ibrahim W, et al. The effects of fish oil and isoflavones on delayed onset muscle soreness. *Med Sci Sports Exerc.* 2002 Oct;34(10):1605–13.
102. Gray P, Chappell A, Jenkinson AM, Thies F, Gray SR. Fish oil supplementation reduces markers of oxidative stress but not muscle soreness after eccentric exercise. *Int J Sport Nutr Exerc Metab.* 2014;24(2):206–14.
103. Nédélec M, Halson S, Delecroix B, Abaidia A, Ahmaidi S, Dupont G. Sleep hygiene and recovery strategies in elite soccer players. *Sports Med.* 2015:1–13.

Submit your next manuscript to BioMed Central and we will help you at every step:

- We accept pre-submission inquiries
- Our selector tool helps you to find the most relevant journal
- We provide round the clock customer support
- Convenient online submission
- Thorough peer review
- Inclusion in PubMed and all major indexing services
- Maximum visibility for your research

Submit your manuscript at
www.biomedcentral.com/submit

